ITC-WRS department

Rioni River, Georgia: Study case in Hec-Ras

Practical

Gabriel Parodi
7/1/2011

Rioni River: Study case in HECRAS

Goal of this practical

To set up a basic HEC RAS model for the Rioni river in Georgia, execute an initial run and evaluate the errors and results. The river produces flooding during summer time as a consequence of a combination of situations: melting of snow, insignificant slope and the Black sea boundary condition, plus eventual rainfall.

Secondary objectives

- Use georeferenced background maps to support the river network construction.
- Input of georeferenced cross section (x, y, z)
- Input of hydraulic parameters of the cross section
- Steady state analysis: input of profiles and boundary conditions
- Unsteady state analysis: input of hydrograph and other boundary conditions
- Modelling lateral inflow, if any.
- Model run and analysis of errors
- A glance to bridge and culverts input. (Separated exercise, optional).

NOTES:

This practical concentrates on the HECRAS model input, analysis and output. No use of the GEO HECRAS interface is made.

We make use of HECRAS (2011) version 4.1.0 for this exercise.

Acknowledgments

Some information in this practical was extracted from the Msc Thesis of Tamar Tsamalashvili. ITC, 2010, ESA department. She also translated this exercise into Georgian language to be use at CENN training course in Bachulari Green Center, Georgia.
Much of the material, suggestions and advices for this exercise were done by Dr. Menno Straatsma from ESA department, ITC, Netherlands. To Tamar and Menno I offer my sincere gratitude.

Data available for this practical

- Rioni Georeferenced topographic map of the Rioni Downstream basin containing all the available cross sections measured in a local Survey.
- Cross sections: There are 44 cross sections for this exercise. Cross sections are named with numbers, from upstream (higher numbers) to downstream (lower numbers). They are in a .csv format, so readable with Excel software.

The format of these files looks like in Table 1.
The first 2 columns are the X and Y coordinates of the levelled station (UTM WGS84, zone 37), the third column the elevation from a predefined datum and the fourth column is the progressive across the section.
This format in excel allows direct import into HECRAS.

The following figure shows the location of the cross sections, and the sketch of the river (the sketch is shifted for clarity).
Cross sections are shown with a colour look up table that shows higher (elevated) points in red, lower in blue and intermediates in a scale from red to blue.

Table 1: format of the cross section information

Xsection = 19			
723331.4	4674005	3.25	0
723340.3	4674016	2.13	13.95869
723342.2	4674018	0.64	16.87948
723342.8	4674019	-0.22	17.73861
723346	4674023	-0.43	22.74233
723349.2	4674027	-0.49	27.73963
723352.4	4674031	0.51	32.74335
723355.6	4674034	-0.6	37.74065

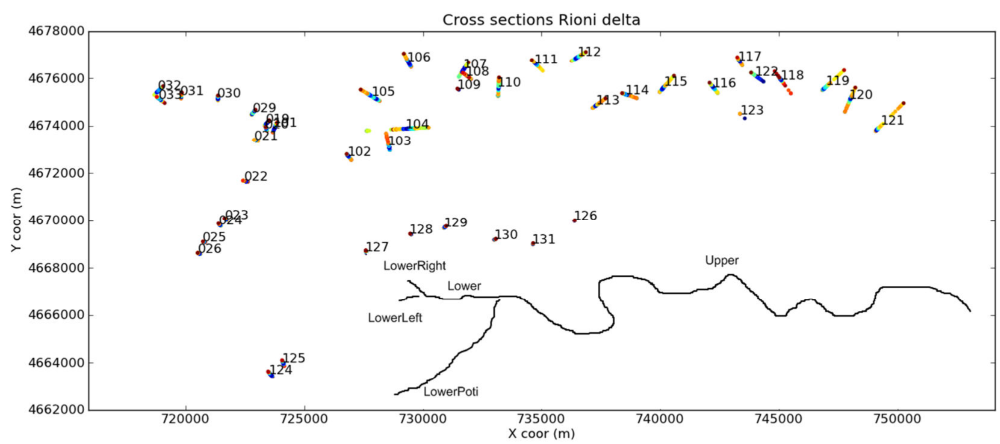


Figure 1: Cross sections measured in the Rioni river

HEC RAS analysis

The following sections summarize the steps in the HECRAS software to model the section of the Rioni river mentioned earlier. The HECRAS manual is required for consultation and details.

Input

1 Make a working directory in your hard drive with Windows explorer or other File manager: create the directory RioniHR in the D: drive (Use the C: drive if D: is not available). For this exercise, this directory will be already created after unzipping the packed exercise file.

2 Open HecRas 4.1.0.

3 Select metric units for the entire project: **Options-Unit System**, select **System International (metric)- OK**.

4 Creating a new project: From main menu: **File-New Project**. Navigate to your recently created working directory and type a **title** and the **file name** for the project. (I.e.: RioniHR for both) – **OK**

In the following we will enter the geometric data of the project.

Entering the background image and the river sketch

5 Press the icon "**Edit/enter geometric data**". The geometric user interface appears.

6 Enter the georeferenced background for the project by pressing the **Add/Edit background picture** for the schematics. Select the Geotif file: Rionitopo.tif and add it to the project. The image has coordinates but HECRAS may display a coordinate extension that extends much beyond the boundary coordinates of the image. This is not a critical issue but is convenient to correct it.

6.1 Say **"yes"** if you are asked to extend the coordinates of the map. Close the add background user interface.

6.2 The map might not display and the working area remains blank. To solve it, anywhere in the working area right click and type **Set Schematics Plot Extent – Set to Computed Extents – OK**. After that, the topographic map should be visible. You can use the context sensitive menu to do panning, zooming and other visualization options on the map. *Notice that the map has coordinates.*

6.3 Warning: Notice that despite that the map has coordinates, the map remains as a background object only for displaying purposes. This means that extreme care should be placed during the input of cross sections data.

In the following we will create the schematics of the river and reaches;
In the Figure 1 and Table 2 we describe the identifiers for the project:

Table 2: River & branches

River	Branch
Rioni	Upper
Rioni	Lower
Rioni	LowerRight
Rioni	LowerLeft
Rioni	LowerPoti

There is one river (Rioni) divided in 5 sections (branches) as schematically described in Table 2 and Figure 1
There are 2 junctions in the model (Table 3).

Table 3: Junctions in the model representation.

Junction number	Joined branches
Junction 1	Lower, LowerPoti & Upper
Junction 2	LowerRight, LowerLeft & Lower

7 In the geometric data interface, select the pencil ("river reach") and carefully digitize the Rioni upper branch. **Always the digitizing should be made from upstream to downstream**. You can use tools as zoom in, out, panning from the context sensitive menu and add points and move points from the "Edit" menu.

IMPORTANT:

7.1 You digitize the deeper section in the river, however this remains as a schematics.

7.2 The cross sections will always be perpendicular to this river reach

7.3 The digitizing ends with a double click at the end of the branch or at the junction.

8 When you end up the digitizing process, you will be requested with the name of the river and the name of the branch. Write down the names given in Table 2. It is Case sensitive, so type it as it is given in the Table 2 (respect the Capital letters and with no spaces).

8.1 When you start or end in a junction, the name of the junction will be requested by the software.

At the end of the digitalization process (a portion) of the upper reach should be like this:

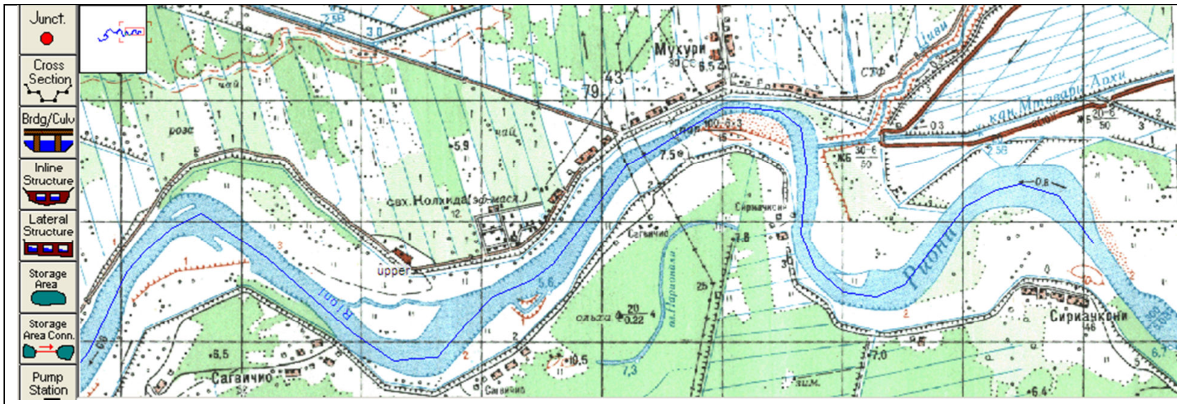


Figure 2: Aspects of the digitalization of the Rioni - Upper

9 Repeat the procedure for the other 4 branches.

At the end of the process, all river and branches should look like in Figure 3, Figure 4 and Figure 5 show a detail of the junctions.

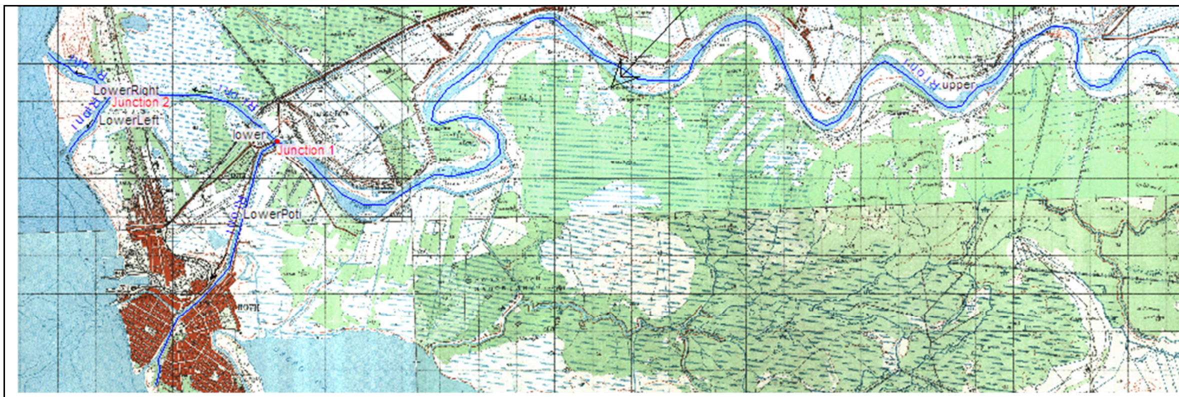


Figure 3: river and reaches after digitalization

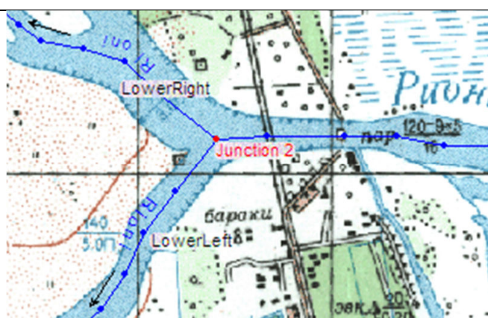


Figure 4: Detail of the junction downstream

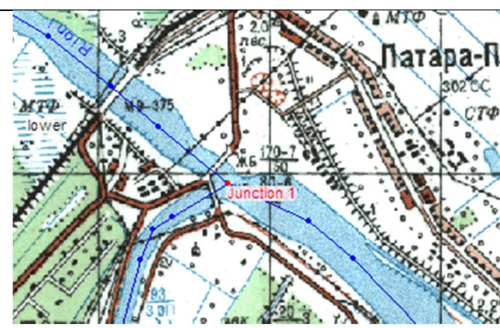


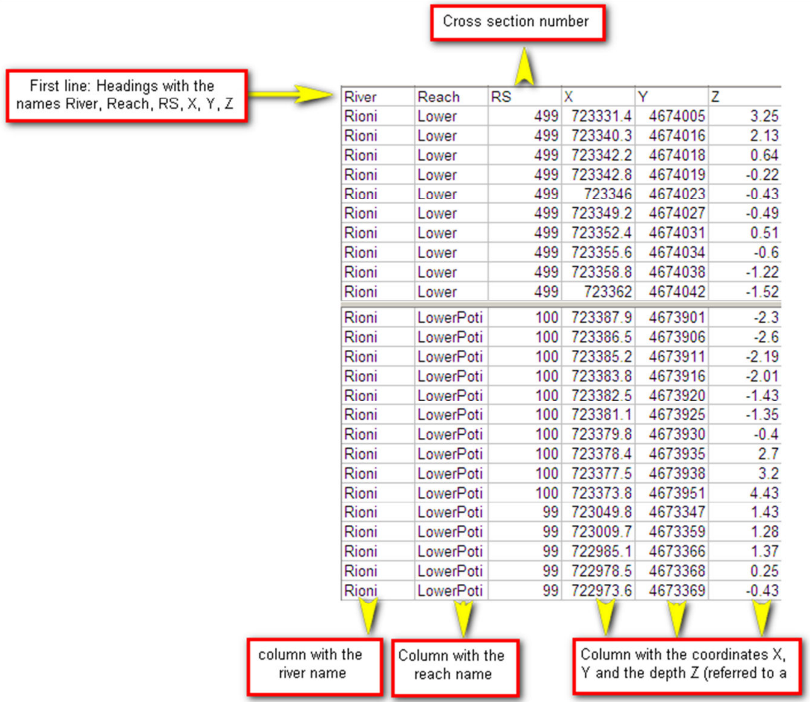
Figure 5: Detail of the junction upstream

This ends up the graphical input of the river reaches.

Importing the cross sections

In the following we will import from one (1) .csv file all cross section (XS) into the HECRAS project. Cross sections have been surveyed in the field with high precision instruments. A single Excel file can be created containing the geometry of each XS (see Table 1). The format of this Excel file should follow some specifications to facilitate the input into Hec Ras.

In the following we look at one of import methods into HECRAS. Open the file XsecHECRAS.csv from your working directory. Excel will be the default software to open the file. The file looks like in Figure 6.



River	Reach	RS	X	Y	Z
Rioni	Lower	499	723331.4	4674005	3.25
Rioni	Lower	499	723340.3	4674016	2.13
Rioni	Lower	499	723342.2	4674018	0.64
Rioni	Lower	499	723342.8	4674019	-0.22
Rioni	Lower	499	723346	4674023	-0.43
Rioni	Lower	499	723349.2	4674027	-0.49
Rioni	Lower	499	723352.4	4674031	0.51
Rioni	Lower	499	723355.6	4674034	-0.6
Rioni	Lower	499	723358.8	4674038	-1.22
Rioni	Lower	499	723362	4674042	-1.52
Rioni	LowerPoti	100	723387.9	4673901	-2.3
Rioni	LowerPoti	100	723386.5	4673906	-2.6
Rioni	LowerPoti	100	723385.2	4673911	-2.19
Rioni	LowerPoti	100	723383.8	4673916	-2.01
Rioni	LowerPoti	100	723382.5	4673920	-1.43
Rioni	LowerPoti	100	723381.1	4673925	-1.35
Rioni	LowerPoti	100	723379.8	4673930	-0.4
Rioni	LowerPoti	100	723378.4	4673935	2.7
Rioni	LowerPoti	100	723377.5	4673938	3.2
Rioni	LowerPoti	100	723373.8	4673951	4.43
Rioni	LowerPoti	99	723049.8	4673347	1.43
Rioni	LowerPoti	99	723009.7	4673359	1.28
Rioni	LowerPoti	99	722985.1	4673366	1.37
Rioni	LowerPoti	99	722978.5	4673368	0.25
Rioni	LowerPoti	99	722973.6	4673369	-0.43

Figure 6: Single excel file containing the information of the stations of a certain number of cross sections. The first line is the heading and it is fixed. Then there is one line for every single station. The first column is the river, the second the river branch, the third the XS number, the fourth and fifth the X and Y coordinates and the sixth is the depth with respect to an arbitrary datum (in this case).

The file can be imported into HECRAS in a single move. It is very important to check the integrity and correctness of the *.csv file. There should be no mistake in the river reach or branch names. User must respect the exact names as entered in the river sketch as they are Case sensitive.

10 To import the XS, from the “Geometric Data” interface select: **File – import geometric data – CSV (Comma Separated Value)**.

10.1 Select the **XsecHECRAS.csv** file and click OK.

10.2 Select **X, Y, Z Format – OK – SI (metric) units – next**

10.3 Unselect all the River Reach Stream (lines were digitized and they will not be imported **– next**

10.4 Unselect: Bridges and Culverts, Inline Structures and Lateral Structures. Leave all other options

10.5 Click “**Finish – Import Data**”. As you finish with the import, the plan should look like:

Figure 7: Imported cross sections into HECRAS. Notice that the cross sections are imported in the right position.

Verification of the positions of the XS

For the sake of verification, look at the csv file, locate any XS and compare the coordinates of the XS ends with the position in the “Geometric Data editor”. To do that, just place the arrow as good as possible on top or the end and compare the coordinates. See Figure 8.

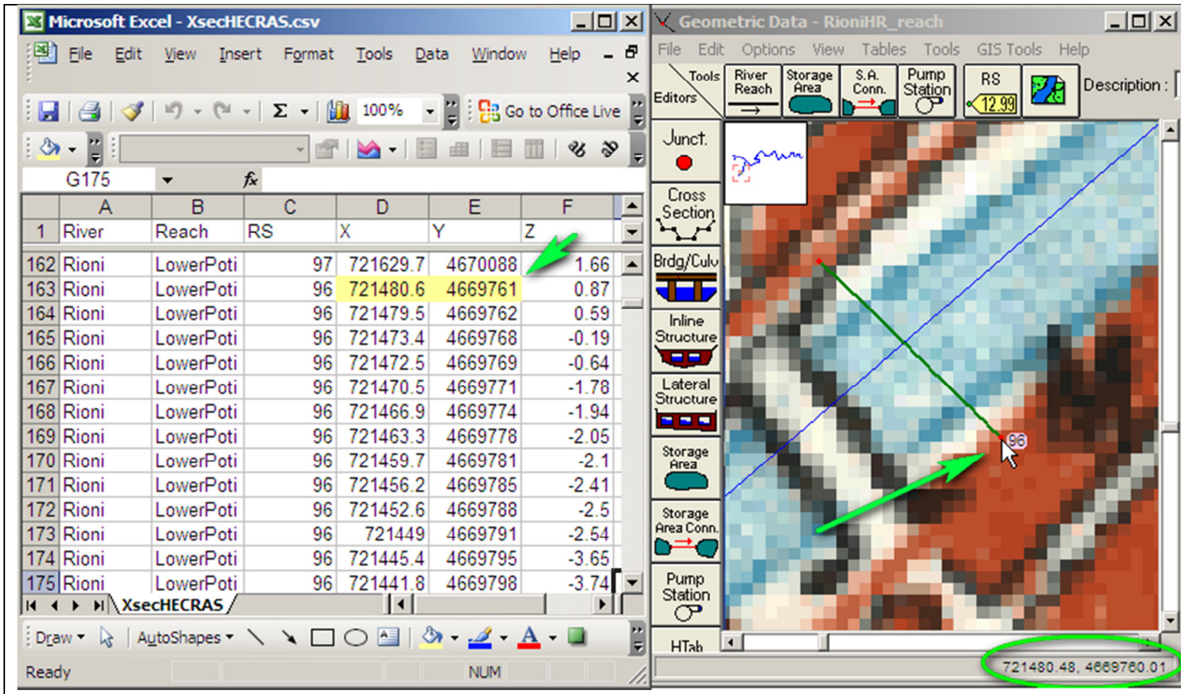


Figure 8: The verification of one XS. The coordinates in the CSV file for a selected cross section coincides with the coordinate in the geometric data editor. This can be checked in the lower-right sector of the Geometric data editor were the coordinate appear. 1 or 2 meter error is normal.

Adding cross sections

In the previous section all XS were added by importing from an excel file. This would be enough for this exercise. However, in real situations, there are many options to enter XS in HECRAS. The most common case is that the XS survey in the field produces a number of XS that prove not to be in enough number to make the HR model stable. In these cases it is recommended to come back to the field, measure some more XS and incorporate them in the model.

To add XS manually click the 

button in the geometric data editor. As from this point follow the instruction in the HECRAS User Manual. Chapter 4: Entering Cross section Data. Understanding this procedure is required for the multiple editions that are normally required before getting a successful run.

Fine tuning the input XS[1]

Up to now, the input limits to the geometry of individual cross sections that fit in the river schematics. There are several additions, modifications and verifications to incorporate at every XS.
The main ones are:

- Check of the slope correctness
- Lengths of the downstream reaches: LOB-channel-ROB
- Establishment of the exact left and right banks.
- Verification of the XS correctness
- Manning coefficients: LOB-channel-ROB
- Eventually some modification to the sections as: levees, flow impediments, ineffective flows.

Slopes

The slope is the most sensitive parameter in any hydraulic model. Slope is not directly input in HECRAS but it is calculated based on the XS elevation and the distances between the XS.
From upstream to downstream all cross sections should reduce elevation.

11 In the Geometric Data Editor, Press the Cross section button. Figure 9 shows the cross section data editor and the option "**Keep Prev XS Plots**" This option leave on cross section on the screen and plot the next one selected by the user.

In the case of the Figure 9 the most upstream section of Rioni-Upper is compared to the most downstream of this reach. It can be observed the vertical differences between these 2 positions (Only 4

[1] CHECK POINT of the exercise. (Students should finish here the first day)

few meters in about 33 km), if banks are available for one profile, then the conveyance section can also be compared. This check is essential as the slopes should be accurate.

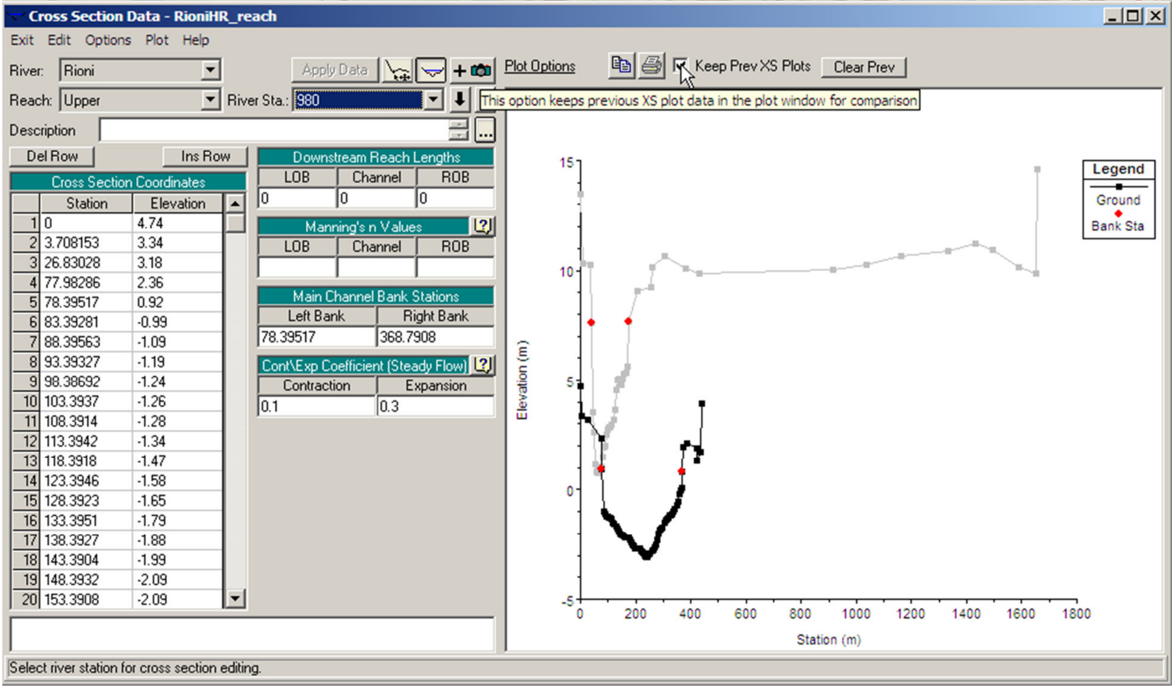


Figure 9: In the cross section data editor, the option "Keep Prev XS Plots" allows the user to see elevations of related cross sections in one display. Adequate to check relative altitude and compare the capacity carrying.

Reaches

The downstream reach is the distance [m] between one XS and the next one downstream.
There are 3 distances to be entered: One for the Left OverBank (LOB), for the main Channel and for the Right OverBank (ROB). To define left or right for a XS, HECRAS always assume that you observe the corresponding XS while standing upstream of it and looking downstream. This is essential; otherwise all the cross sections will be reverted.

Why three distances? HECRAS divides the flow into three sections: flow in the channel and flow in the right and left banks to calculate different conveyances. If the consecutive sections are aligned then the 3 distances are identical.

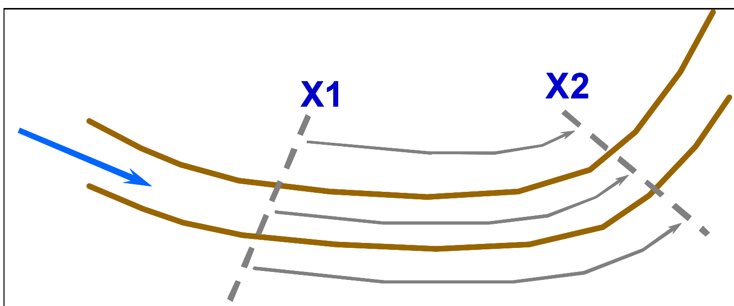


Figure 10: Distances between XS (X1 and X2) in the LOB, Channel and ROB are different: LOB distance is the shortest and ROB the longest.

The distances are to be measured along the centerlines of the LOB, channel and ROB.

The spreadsheet "distances.xls" contains the distances between the cross sections in the three sectors. The spreadsheet contains the information depicted in the following Table 4.

Table 4: Distances between the cross sections. Colors indicate the group of distances composing each reach for easier visualization. Lines in white are used to enter the distances between the cross sections at the junctions and not at the reaches.

From section in	River	Section	Station	to section in	River	Section	Station	LOB dist	Chan. Dist	ROB dist
121	Rioni	Upper	999	120	Rioni	Upper	998	1528.454488	1716.975875	2137.524147
120	Rioni	Upper	998	119	Rioni	Upper	997	1313.813733	1192.651113	869.7734316
119	Rioni	Upper	997	118	Rioni	Upper	995	1334.632504	1883.480961	2928.121728
118	Rioni	Upper	995	117	Rioni	Upper	994	2371.592491	1902.832774	1686.061803
117	Rioni	Upper	994	116	Rioni	Upper	993	1558.787883	1571.991147	1592.670809
116	Rioni	Upper	993	115	Rioni	Upper	992	2444.866847	2051.114826	1525.431458
115	Rioni	Upper	992	114	Rioni	Upper	991	1000.601016	1584.693503	2307.154927
114	Rioni	Upper	991	113	Rioni	Upper	990	1901.777702	1356.329832	734.4262016
113	Rioni	Upper	990	112	Rioni	Upper	989	2174.92248	2170.695341	2133.190248
112	Rioni	Upper	989	111	Rioni	Upper	988	1290.882885	1800.61478	2302.572431
111	Rioni	Upper	988	110	Rioni	Upper	987	2165.729308	1844.1354	1569.479534
110	Rioni	Upper	987	107	Rioni	Upper	986	1845.055909	1646.182329	1437.07408
107	Rioni	Upper	986	106	Rioni	Upper	985	2060.425581	2371.554091	2754.611311
106	Rioni	Upper	985	105	Rioni	Upper	984	1954.07621	2063.064171	2376.287934
105	Rioni	Upper	984	104	Rioni	Upper	983	2346.902039	1863.114474	1746.972291
104	Rioni	Upper	983	103	Rioni	Upper	982	1900.676057	1108.247681	828.4782951
103	Rioni	Upper	982	102	Rioni	Upper	981	1673.172897	1791.341456	1883.443104
102	Rioni	Upper	981	101	Rioni	Upper	980	3515.382117	3272.886186	3227.600744
101	Rioni	Upper	980	19	Rioni	Low er	499	440.0792396	**376.5461044**	342.6225035
19	Rioni	Low er	499	29	Rioni	Low er	498	715.7172944	730.0241284	726.7054174
29	Rioni	Low er	498	30	Rioni	Low er	497	1543.646417	1582.264405	1688.315908
30	Rioni	Low er	497	31	Rioni	Low er	496	1555.100615	1548.581879	1534.844842
31	Rioni	Low er	496	32	Rioni	Low erRight	400	1143.051796	**1029.544152**	829.4170596
	Rioni	Low erRight	400		Rioni	Low erRight	350	1462.8	1402.8	1402.8
101	Rioni	Upper	980	20	Rioni	Low erPoti	100	257.8695645	**380.9107522**	503.5348788
20	Rioni	Low erPoti	100	21	Rioni	Low erPoti	99	575.4102042	681.9819538	742.1292232
21	Rioni	Low erPoti	99	22	Rioni	Low erPoti	98	1774.558498	1779.680911	1783.082478
22	Rioni	Low erPoti	98	23	Rioni	Low erPoti	97	1853.850981	1818.788981	1769.296505
23	Rioni	Low erPoti	97	24	Rioni	Low erPoti	96	345.9986364	342.5203532	339.50095
24	Rioni	Low erPoti	96	25	Rioni	Low erPoti	95	968.3809893	984.7772646	1003.713871
25	Rioni	Low erPoti	95	26	Rioni	Low erPoti	94	529.1454756	527.895999	526.9390391
31	Rioni	Low er	496	33	Rioni	Low erLeft	300	717.1371224	**898.3780316**	1068.176719
	Rioni	Low erLeft	300		Rioni	Low erLeft	250	1402.77	1402.77	1402.77

To operate with this table, as an example we take the first line below the heading.
At the Rioni River in the upper section, from station 999 to 998 the distances are highlighted in dark yellow. Figure 11 shows the schematics between the 2 sections and it can be seen that indeed the LOB distance is smaller than the other 2.

12 From the **Geometric Data Editor menu** select **Tables-Reach Lengths**. A table opens and the user can copy the distances from the excel sheet and paste it directly in this table. Use the column "**Station**" as the reference (key column). This table is an addition to HECRAS that allows entering all the section distances at once. At the end of the copy and paste process the Interface for the Rioni – Upper should look like in Figure 12. *Last section of each reach should be set distance 0*. Press OK to save the data and the repeat the procedure for all branches. Figure 13 to Figure 16 show the outcome of this last procedure.

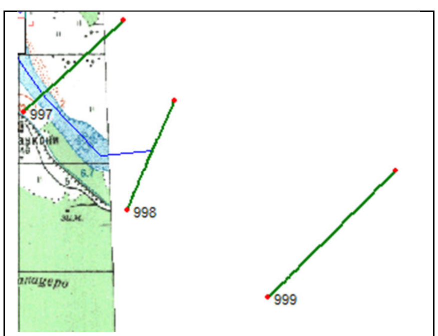
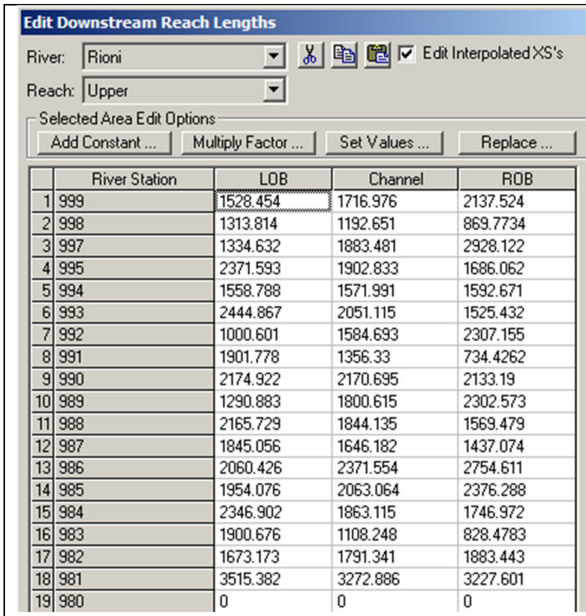
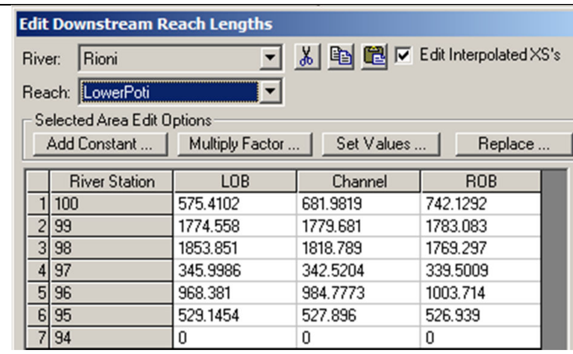


Figure 11: The distance between 999 and 998 is different for the LOB, channel and ROB. The ROB is the longest.



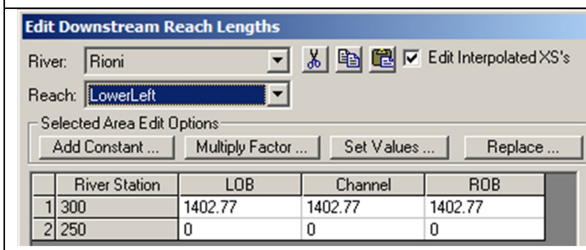
	River Station	LOB	Channel	ROB
1	999	1528.454	1716.976	2137.524
2	998	1313.814	1192.651	869.7734
3	997	1334.632	1883.481	2928.122
4	995	2371.593	1902.833	1686.062
5	994	1558.788	1571.991	1592.671
6	993	2444.867	2051.115	1525.432
7	992	1000.601	1584.693	2307.155
8	991	1901.778	1356.33	734.4262
9	990	2174.922	2170.695	2133.19
10	989	1290.883	1800.615	2302.573
11	988	2165.729	1844.135	1569.479
12	987	1845.056	1646.182	1437.074
13	986	2060.426	2371.554	2754.611
14	985	1954.076	2063.064	2376.288
15	984	2346.902	1863.115	1746.972
16	983	1900.676	1108.248	828.4783
17	982	1673.173	1791.341	1883.443
18	981	3515.382	3272.886	3227.601
19	980	0	0	0

Figure 12: Final distances between the cross sections for the Upper reach.



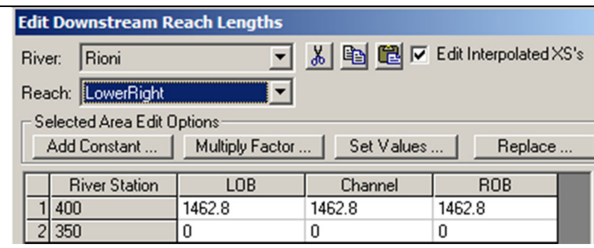
	River Station	LOB	Channel	ROB
1	100	575.4102	681.9819	742.1292
2	99	1774.558	1779.681	1783.083
3	98	1853.851	1818.789	1769.297
4	97	345.9986	342.5204	339.5009
5	96	968.381	984.7773	1003.714
6	95	529.1454	527.896	526.939
7	94	0	0	0

Figure 13: Final distances between the cross sections for the LowerPoti reach.



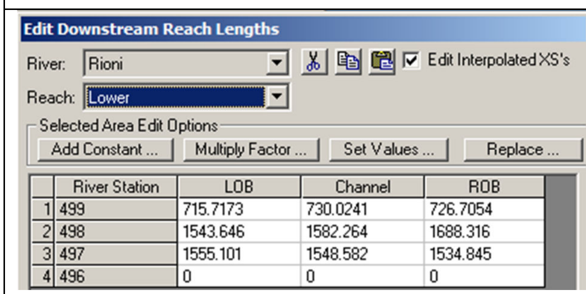
	River Station	LOB	Channel	ROB
1	300	1402.77	1402.77	1402.77
2	250	0	0	0

Figure 14: Final distances between the cross sections for the LowerLeft reach.



	River Station	LOB	Channel	ROB
1	400	1462.8	1462.8	1462.8
2	350	0	0	0

Figure 15: Final distances between the cross sections for the LowerRight reach.



	River Station	LOB	Channel	ROB
1	499	715.7173	730.0241	726.7054
2	498	1543.646	1582.264	1688.316
3	497	1555.101	1548.582	1534.845
4	496	0	0	0

Figure 16: Final distances between the cross sections for the Lower reach.

Left and right banks

The next step is the establishment of the left and right banks (LB and RB). By default HECRAS assumes that the first and last station of each XS is the LB and RB respectively. This must be corrected in order to assign the correct roughness. Keep in mind that the channel is not the area where the water was flowing in the survey, but the area where the water could flow without producing a flooding to the overbanks.
During the XS survey, the surveyor should make specific notes on which is the beginning and end of the channel and the overbanks. In this way the process of informing this to HECRAS is easier an accurate. Photo 1 gives some guidelines on channel determination and roughness.

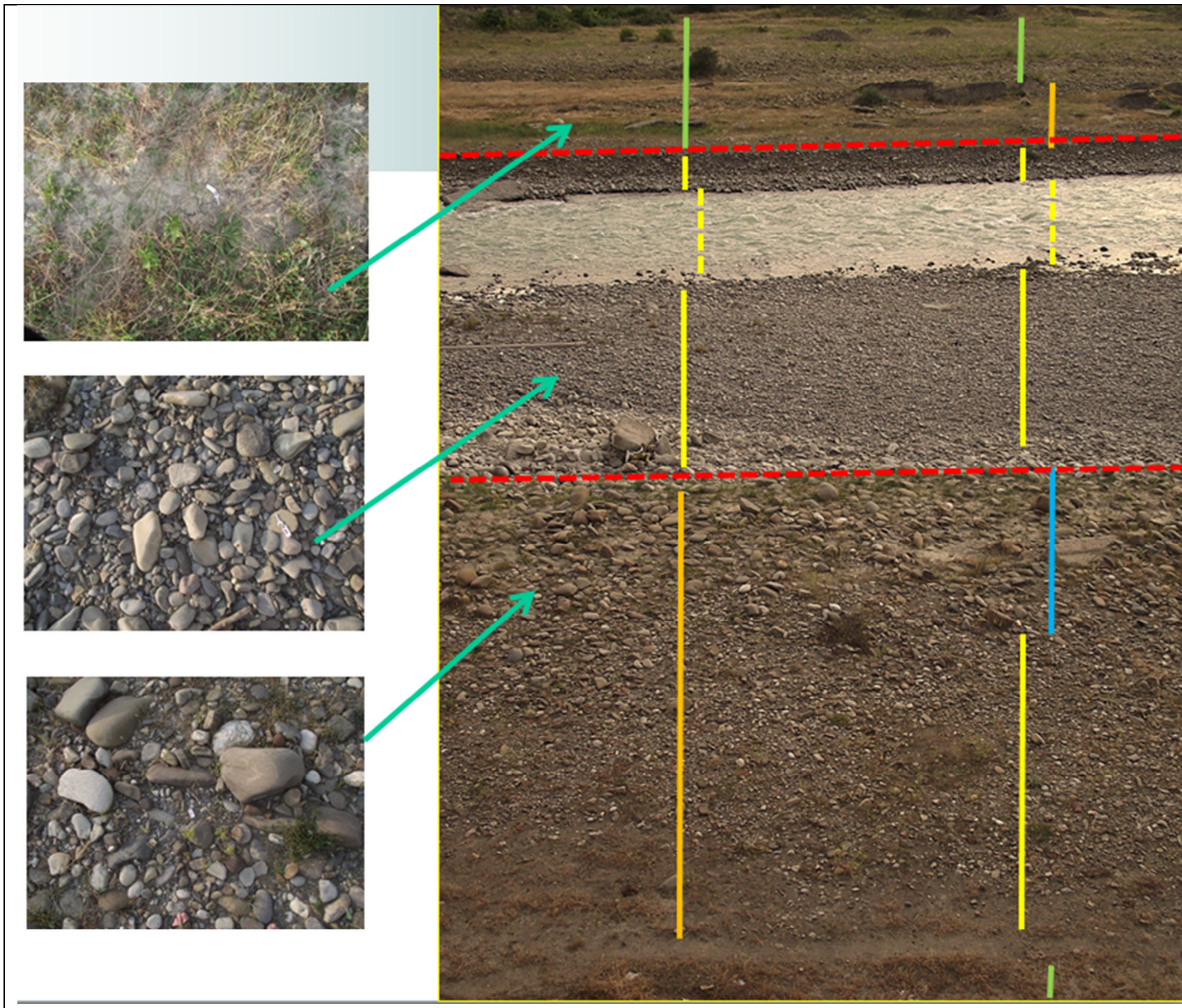


Photo 1: A river section seen from the point of view of HECRAS. The river was flowing from right to left. The dashed redlines show the position of the channel area. At the moment of the photo, the water was not covering the whole channel. Left and right of the channel area are the Left and Right overbanks. The characterization of the Manning is shown with the vertical color lines. On the left there are 3 different Mannings, for the LOB, channel and ROB. To to right a more detail characterization of the Manning where the surveyor observed more than one Manning at the overbank. The three photographs to the left are details of the roughness.

For this specific exercise, the surveyor was instructed to make one leveling station at the site were the water start flowing at the channel banks while doing the XS. This is not strictly needed.
In some occasions this was not explicitly indicated so for this exercise, we will use the banks available in the “Bank_position.xls” file as depicted in Table 5.

13 From the **Geometric Data Editor menu** select **Tables-Bank stations**. A table opens and the user can copy the LOB and ROB from the excel sheet (Bank_positions.xls) and paste it directly in this table. The user can (and normally should) enter the bank stations from the Cross section editor as the control is easier.

XS correctness

All cross sections should be correctly entered in HR. Parameters to check are: altitude, progressive, position of the banks and to ensure that the sections are entered in HR from Left to Right while looking at the section from upstream.
These lasts two must be checked by the surveyor.

The Surveyor of the Project Mr. Beso Kavtaria informed that XS 99 in the LowerPoti has an error in elevation at station 102.90 that was not corrected in the .CSV file with the cross sections.
The elevation was wrongly set to +2.98 meter when it should be -2.98 m. Figure 17 and Figure 18 indicates how the correction is done.

These days we could use actual remote sensing imagery to check for some inconsistencies.
We have imposed the surveyed sections over the topographic sheets of the region. The topographic sheets are rather old when compared to the time needed for river shifting after flood events.

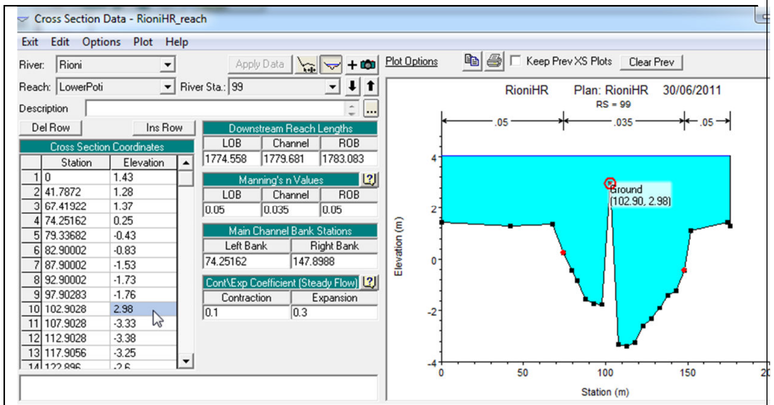


Figure 17: Correcting an error in a cross section: Step 1- in the **cross section editor** select the station with the wrong information in the graphic. Each point is linked to the table and the corresponding line illuminates.

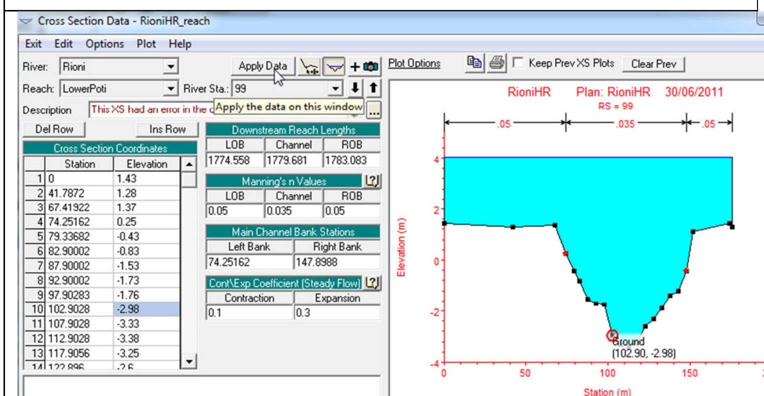


Figure 18: Replace 2.98 by -2.98 and press Enter and "Apply Data". The correction is done.

Table 5: Location of the left and right banks for the exercise.

Rioni	Upper	Station	LB	RB
Rioni	Upper	999	39.2164	173.7231
Rioni	Upper	998	415.3911	714.1473
Rioni	Upper	997	26.9971	358.8814
Rioni	Upper	995	628.4857	811.7066
Rioni	Upper	994	163.7795	316.4474
Rioni	Upper	993	185.5783	448.1818
Rioni	Upper	992	122.3074	338.0531
Rioni	Upper	991	413.8105	629.6625
Rioni	Upper	990	115.5729	235.2978
Rioni	Upper	989	147.0112	477.0745
Rioni	Upper	988	336.399	532.8262
Rioni	Upper	987	235.3895	623.1122
Rioni	Upper	986	238.9954	570.3682
Rioni	Upper	985	50.82591	387.6337
Rioni	Upper	984	111.9207	596.913
Rioni	Upper	983	575.2067	1082.522
Rioni	Upper	982	7.124057	287.6621
Rioni	Upper	981	149.702	312.6601
Rioni	Upper	980	78.39517	368.7908
Rioni	Lower	499	16.87402	252.8303
Rioni	Lower	498	4.406382	241.232
Rioni	Lower	497	40.2653	195.065
Rioni	Lower	496	51.0341	162.3025
Rioni	LowerRight	400	131.3298	481.2428
Rioni	LowerRight	350	131.3298	481.2428
Rioni	LowerLeft	300	157.5632	419.5128
Rioni	LowerLeft	250	157.5632	419.5128
Rioni	LowerPoti	100	11.98201	153.2415
Rioni	LowerPoti	99	74.25162	147.8988
Rioni	LowerPoti	98	50.06245	143.542
Rioni	LowerPoti	97	21.74888	99.82433
Rioni	LowerPoti	96	11.35721	99.15968
Rioni	LowerPoti	95	26.98104	90.65729
Rioni	LowerPoti	94	6.614233	100.5253

Figure 19 shows a case where the measured cross sections banks fit perfectly well the maps. This give as confidence that the section is stable and the input was done correctly in HecRas.
Figure 20 shows a deposition area or a sand dune in the topographic map at the position where the actual water section is now flowing.
Figure 21 shows the actual channel shifted from the original position. This could be a mistake product of inverting the stationing data (the XS was input from right to left). It could also be another kind error that may lead to review the pre-processing done to the raw point survey data or eventually it would be necessary to repeat the XS.

INFORMATION ONLY: There is an option in HR to reverse the stationing order: from the **Geometric Editor Data – Tools – Reverse stationing data.**

In our case, we are confident that all the sections are well input in HR and the mismatch is product of river dynamic shifts.

Manning coefficients

The next step is the assignation of the Manning coefficients of roughness. Manning coefficients can be assigned in two ways in HECRAS:

a- One single Manning for LOB, ROB and Channel per cross section is adopted. At the end 3 Manning's in total per XS.
b- Manning can change along the progressive of the section regardless the position.

See an example in Photo 1 and read the HECRAS User manual about these alternatives.

Figure 19: Correct banks.

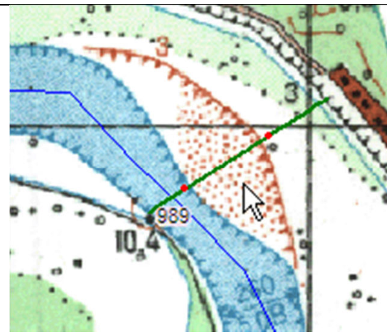


Figure 20: river shifting?

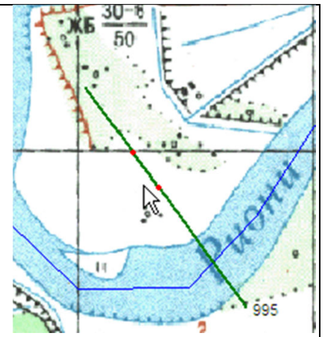


Figure 21: Is a river shifting or a reverse stationing? An error?

During preliminary studies Manning coefficients are obtained from tables available elsewhere. In the HECRAS reference manual there is a standard table where Manning coefficients can be assigned after a description of the river bed at every cross section.
After the model runs, it is very common to fine tune the model by re-adapting the Manning values. This is a process that escapes the objective of this exercise.
In our case, we will adopt that all channel sections have a Manning equal to 0.035 and the Left and Right overbanks 0.050. This kind of generalization is not proper during real modeling.

There are some sections in the river where there is a flow division. The channel splits in two sections and the river flows in 2 parallel sub-channels. Those are the cases of at least 2 stations (987 and 984) in the Upper Rioni depicted in Figure 22 and Figure 23.
For these cases, the horizontal variation of the Manning needs more than 3 options. HecRas can be instructed to account for that from the **cross section data editor**.

14 At the cross section that requires this option, from the cross section editor select: "**Options-Horizontal variation of n values**". A new column "n Val" is added to the "Cross Section Coordinates". The user can enter now a horizontal variation of "n"

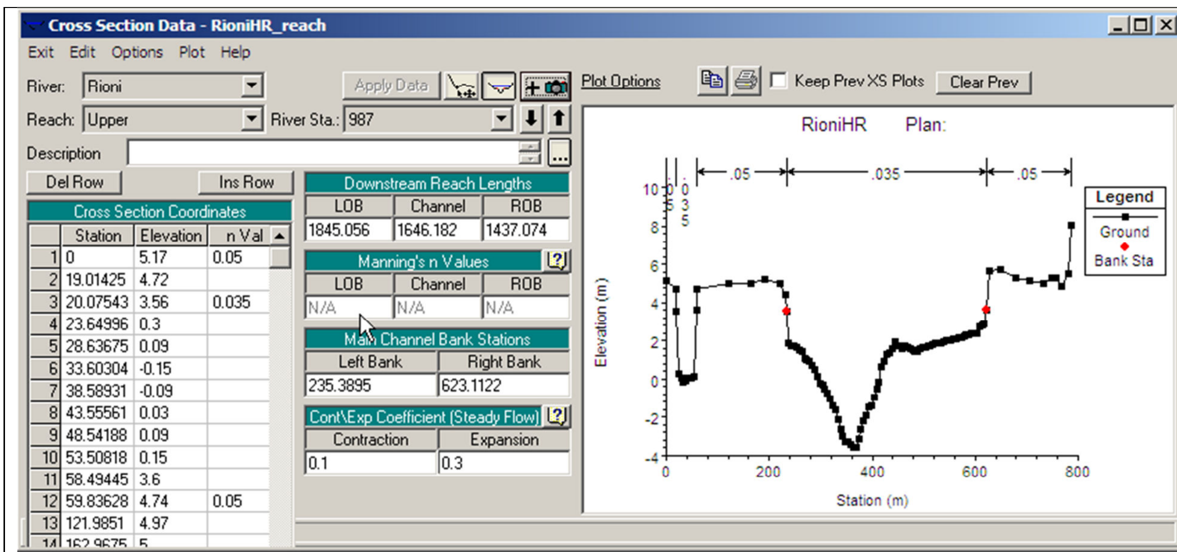


Figure 22: The flow happens over 2 sections in station 987. The horizontal variation of Manning allows to design appropriate Manning's for each portion of the progressive.

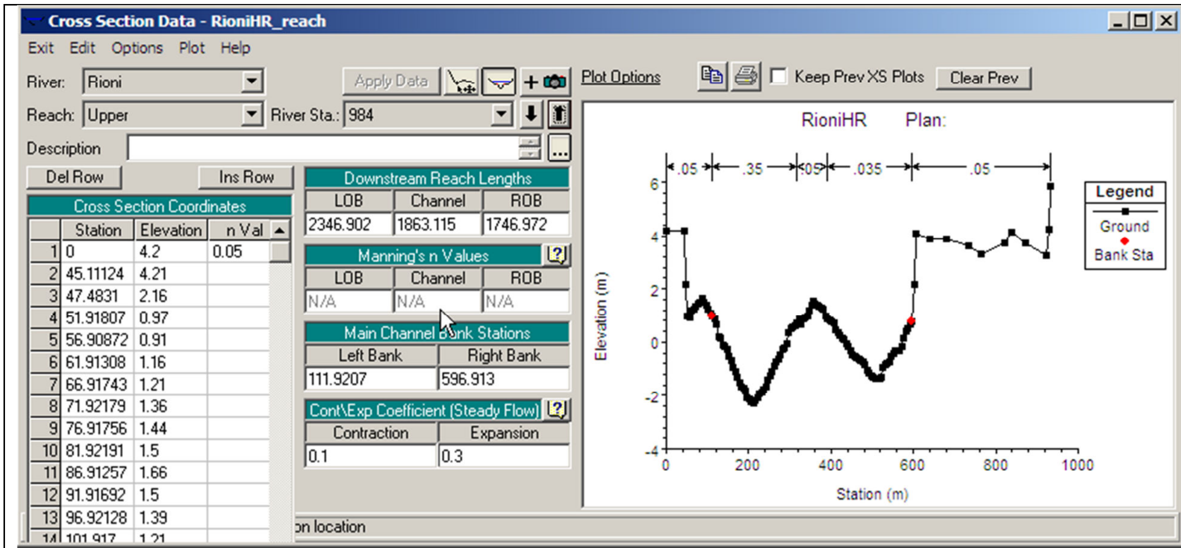


Figure 23: This is a case of parallel flow. HecRas can handle these situations, but roughness partition in three is not enough for this section.

Figure 22 and Figure 23 show 2 cases where parallel flow happens and then Manning needs to be better distributed. Both figures show the changes in the Manning already made. The user may try to reproduce them. *The user only needs to enter the new Manning at the stations where there is a change*. The other stations are handled by the software. Look at the graphical part of Figure 22 and Figure 23. In the upper part the new distribution of the Manning is already indicated. The user should try to reproduce these changes. The objective af these changes is that a Manning of 0.035 should be assignes where the water flows and a value of 0.05 should be assigned at the "islands".

Table 6: Adopted Manning coefficients.

	Reach	River Station	Frctn (n/K)	n #1	n #2	n #3	n #4	n #5	n #6
1	Upper	999	n	0.05	0.035	0.05			
2	Upper	998	n	0.05	0.035	0.05			
3	Upper	997	n	0.05	0.035	0.05			
4	Upper	995	n	0.05	0.035	0.05			
5	Upper	994	n	0.05	0.035	0.05			
6	Upper	993	n	0.05	0.035	0.05			
7	Upper	992	n	0.05	0.035	0.05			
8	Upper	991	n	0.05	0.035	0.05			
9	Upper	990	n	0.05	0.035	0.05			
10	Upper	989	n	0.05	0.035	0.05			
11	Upper	988	n	0.05	0.035	0.05			
12	Upper	987	n	0.05	0.035	0.05	0.035	0.05	0.05
13	Upper	986	n	0.05	0.035	0.05			
14	Upper	985	n	0.05	0.035	0.05			
15	Upper	984	n	0.05	0.35	0.05	0.035	0.05	
16	Upper	983	n	0.05	0.035	0.05			
17	Upper	982	n	0.05	0.035	0.05			
18	Upper	981	n	0.05	0.035	0.05			
19	Upper	980	n	0.05	0.035	0.05			
20	Low erPoti	100	n	0.05	0.035	0.05			
21	Low erPoti	99	n	0.05	0.035	0.05			
22	Low erPoti	98	n	0.05	0.035	0.05			
23	Low erPoti	97	n	0.05	0.035	0.05			
24	Low erPoti	96	n	0.05	0.035	0.05			
25	Low erPoti	95	n	0.05	0.035	0.05			
26	Low erPoti	94	n	0.05	0.035	0.05			
27	Low erLeft	300	n	0.05	0.035	0.05			
28	Low erLeft	250	n	0.05	0.035	0.05			
29	Low erRight	400	n	0.05	0.035	0.05			
30	Low erRight	350	n	0.05	0.035	0.05			
31	Low er	499	n	0.05	0.035	0.05			
32	Low er	498	n	0.05	0.035	0.05			
33	Low er	497	n	0.05	0.035	0.05			
34	Low er	496	n	0.05	0.035	0.05			

Check all cross sections and note down those that this alternative could be needed. Table 6 is the first attempt of Manning's for this model and will be used in this exercise. River stations 987 and 984 have more than 1 channels as the flow is divided as it is seen in Figure 22 and Figure 23.

15 From the **Geometric Data Editor** menu select **Tables-Bank stations**. A table opens and the user can verify the Mannings

already entered. The table should look similar to Table 6, but it is not essential.

This concludes the input of the cross section data.

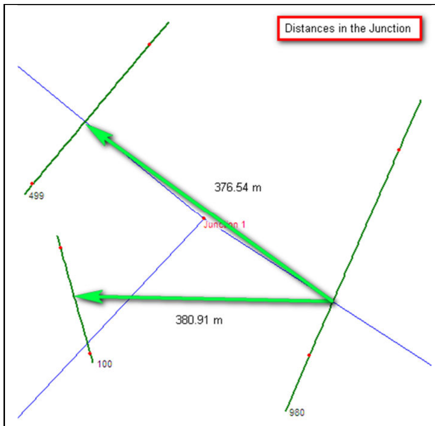


Figure 24: Distances in the Junction 1.

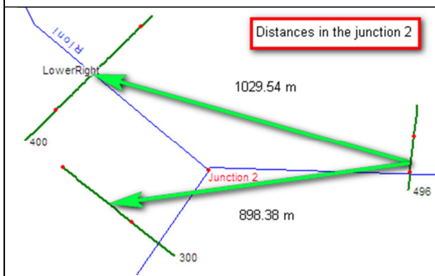


Figure 25: Distances in the Junction 2.

Junctions

There are 2 junctions in the model. In the junctions the user has to enter the reach lengths across the junction, the tributary angle and the calculation method. All this information can be read in the User Manual of HecRas.

16 Press the "**Junction**" button in the **Geometric Data editor**. The first Junction appears
 16.1 Enter Description: "Division Upper into Lower and LowerPoti". Description is only for information.
 16.2 There are two lengths to input:
  16.2.1 From Rioni Upper to Rioni Lower Poti (380.91 m). There is an angle of 30º between the Rioni Upper and the Rioni Poti. The angle will be used in case that Momentum computation mode is selected
  16.2.2 From Rioni Upper to Rioni Lower (376.54 m)

The mentioned distances can be obtained also from Table 4.
The selection of the Method for the Junction calculation must be read from the manual. For steady flow we will select the energy method and for unsteady flow the new energy balance method to overcome the problem that the sections at the junctions are measured very far apart (XS should be measured close to the junction without overlapping).

When all data is added to HECRAS, the user interface for Junction 1 should look like in Figure 26.

17 Repeat the same procedure for Junction 2.
 17.1 Enter a description and the rest of the information. At the end of the process the data input should be like in Figure 27. *If Momentum method is not selected, the input angles will not be stored. This is OK.* Figure 27Figure 27 shows the final outcome.

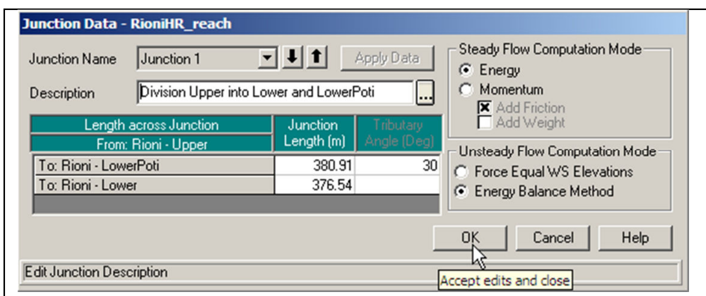


Figure 26: Junction 1 input.

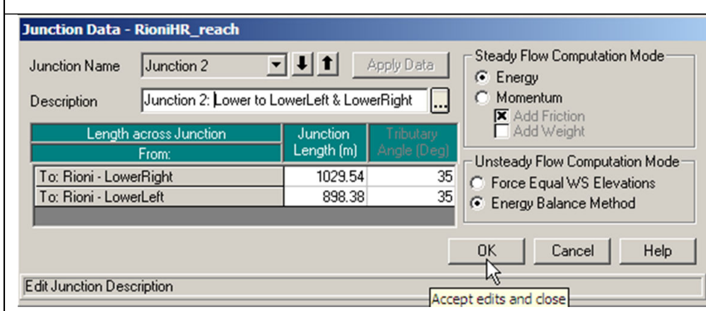


Figure 27: Junction 2 input.

Boundary and initial conditions

The success or failure in a hydraulic model is tight to the selection of adequate boundary conditions (BC). The river system is composed by two exclusive (or) environments: the system under analysis and the elements composing the external influence over the system under analysis. The system is analized in isolation but boundary conditions are required to impose the constraints and forces that the external influences subject the system.

In this exercise two situations will be analyzed: steady and unsteady flow.
The steady flow assumes that at any section in the river system the discharge is constant in time. Two cross sections may have different discharge values, but they will remain always invariable in time. Steady

flow analysis assumes that a constant flow enters the river system for a long period of time till the system stabilizes (input=output). As such it assumes that all sectors able to store water will be filled. In this way steady flow analysis could picture very well the hypothetical case of a long term, long lasting flood. For the same reason, steady flow is not normally used to analize flood peak discharges as this might result in a unreasonable flood estimation. (Floods last less than the time to stabilize the peak)

Unsteady analysis is done to simulate a flood wave coming in the system (hydrograph). It is the standard analysis performed over a flood event.

Initial Conditions refer to the discharge flowing at the beginning of the simulation (time 0). It is common practice that the system is allowed to flow at steady state for few hours before receiving the wave front in unsteady modeling. This prevents some instability in the process. Results of a steady flow analysis may be used as initial conditions in an unsteady flow analysis as well.

Steady flow analysis

There are four kinds of boundary conditions in HECRAS for the steady state: Known water surface, critical depth, normal depth and rating curve.

The outlet of the system is the Black Sea. The level of the Black Sea is affected by tides and inputs and outputs although the water elevation amplitude of the Black Sea is small compared to oceans. The Known Water Surface condition is then appropriate for the downstream outlets in both steady and unsteady situations

Upstream, several "profiles" can be selected. Profiles are just discharges entering the upper section of the system that the user selects based on importance. Each profile is treated independently by the software: if you enter 4 profiles (discharges), there will be 4 independent runs with 4 independent results, although the user can display the results simultaneously for comparison. Normally Profiles are discharges associated to return periods.
There is evidence of a statistical increase of the annual peak discharges in the last years. Flood records are available from 1939 to 1990.

In this example we will set 6 profiles, starting at 500 m³/s and ending at 3000 m³/s, with jumps of 500 m³/s.

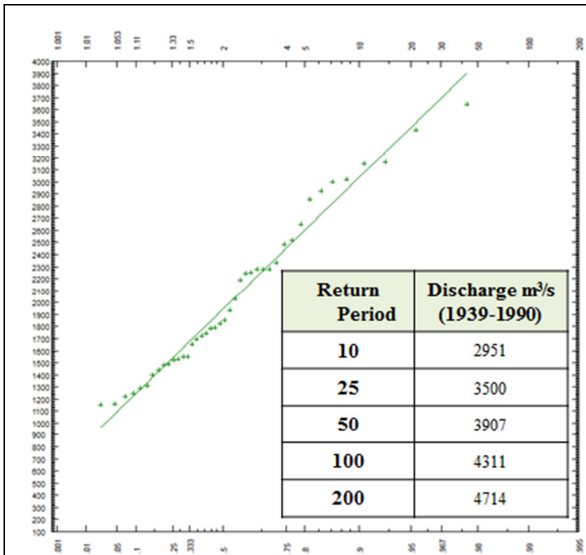
18 In HR main menu, select the icon: "**Edit/Enter steady flow data**". The user should read the user manual for this critical step.

19 The interface asks for a number of profiles and the corresponing flow rates at every reach. Assuming that in the upper Rioni a fix amount of discharge enters the system (i.e. 500 m³/s), the distribution of this amount between the lower, and Poti will depend on the hydraulics of the system or man-made operation of the system. The same for the second junction between the lower and the lowerLeft and lowerRight reaches. The user has two options:

19.1 Impose a flow in every reach (default), regardless of the mass balance at the junction.

19.2 Give and estimation of the flow at every reach and let HecRas to optimize the hydraulic to a proper partition of the flow at every junction.

We will see both alternatives. In either case, the estimated initial flow at every reach needs input.



Return Period	Discharge m³/s (1939-1990)
10	2951
25	3500
50	3907
100	4311
200	4714

Figure 28: Gumbel extreme probabilistic plot. It states the historical records of floods.

Assumption of the flow partitions

In steady flow and in a junction, the sum of the input flow should equal the sum outflow. In this case $Q_{in}= Q_{out1} + Q_{out2}$

For each individual branch 'i' in a junction $Q_i= A_i.V_i$ = constant. As the river is subcritical and the slope negligible, in order to estimate the flow partitions it was adopted that the water speed is similar in the three branches. With this assumption $A_{in}= A_{out1} + A_{out2}$

For the sake of this exercise we assume that the LowerRight and LowerLeft branches have similar cross sections and that the LowerPoti area is 20% and the Lower reach 80% of the upper reach. So, if 'X" is the flow upstream of the upper Rioni into the system, 0.2*X goes into Rioni Poti, 0.8*X into the lowerRioni and 0.5*0.8*X into both the lowerRight and lowerLeft branches.
The user can change these assumptions at any time.

At the end of the input, the interface should look like in Figure 29.

The "**Add Flow Change Location**" button allows the user to add or withdraw discharges at any selected station. This allows the simulation of small tributaries or watersheds without a formal design in HecRas.

20 From the "**Steady Flow Data**" interface select the "**Reach Boundary Conditions**" button.

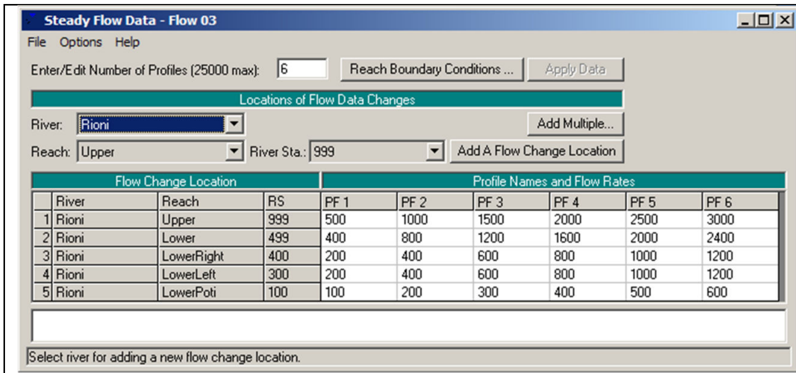


Figure 29: Selected steady flow conditions for this exercise. User can change them at any time.

All internal boundaries (Junctions) are already established and ready.
It remains the definition of the downstream boundaries (at the Black sea) and the upstream boundary at the Upper Rioni Reach.

- If the system is fully subcritical, then, the Upstream boundary is not needed.
- If the system is fully supercritical, then the downstream boundary is not needed.
- If the system has sections in subcritical and others in supercritical, both boundary conditions are needed (mixed flow).

Normally the user would assume that the system is subcritical if the slopes are very gentle (i.e < 1.2%). In any case, the user can assume any regime and after the run will immediately verify if the assumption was right or needs other assumptions.

There is clear evidence that the lower Rioni is fully subcritical and then we need to enter only the downstream boundary conditions.
Out of the four options, we could assume a water elevation in the Black sea and set it to the last XS of the LowerRight, LowerLeft and LowerPoti reaches.
The higher the water level at the Black Sea, the more the backwater effect and the more difficult the drainage. Then this boundary condition is essential to flood analysis.

We will set the BC at 0 level and at + 0.5 m (in two different runs) as example.
Figure 30: shows how the Steady Flow Boundary condition interface opens. Internal boundaries are all set. The user need to add a boundary condition to the three downstream reaches only as we assume subcritical flow.

Figure 31 shows the interface that opens when the "**Known W.S.**" button is pressed. The Water Elevation (absolute elevation referred to the Datum of the project, as the cross sections are).
In the first run we set everything to 0 elevations and in a second run it will be set to +0.3 m.
After the Boundary conditions are settled the interface should look like in Figure 32.

Once the Flow data is completed, it can be saved from the "Steady Flow Data" Interface: **File – Save As** and enter a proper name for this flow data condition (I.e. BC_steady00).

The second Flow Data Condition in steady state is exactly the same as the one above except that the elevation downstream is +0.5 instead of 0.
TIP: To save time, open the "Steady Flow Data" just recently saved and "save as" again with other proper name that represents the new BC. Later, open this newly created dataset and replace the BC downstream for +0.5.

21 From the "**Stream Flow Data" menu: File-Save Flow Data as**" and give a proper name for the new Flow data (I.e. BC_steady05).

The only change is the Reach Boundary conditions downstream.

22 Press the "**Reach Boundary Condition button**".

23 Double click on each "**Known WS**" downstream BC and change the 0 elevation by 0.5.

24 Once is finished Save the Steady Flow Data. (**File-save**).

At the end of this process, two "Steady Flow Data" cases will be available to compute in HecRas.

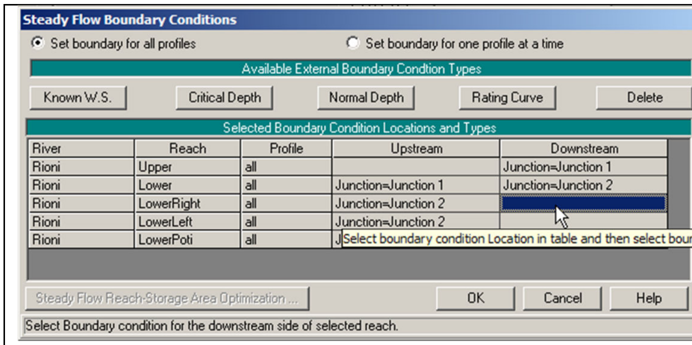


Figure 30: Interface for Steady Flow Boundary condition. Downstream conditions should be established if subcritical flow is assumed. Click In the cell indicated in the figure and then click on "Known W.S". This operation will be repeated for the other downstream reaches

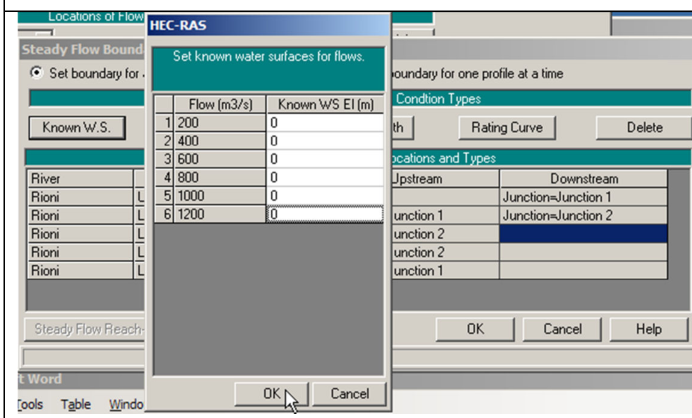


Figure 31: Once clicked "Known W.S." the elevation of the water in the downstream boundary condition must be entered for any profile. Set water level equal 0 for all profiles and all reaches.

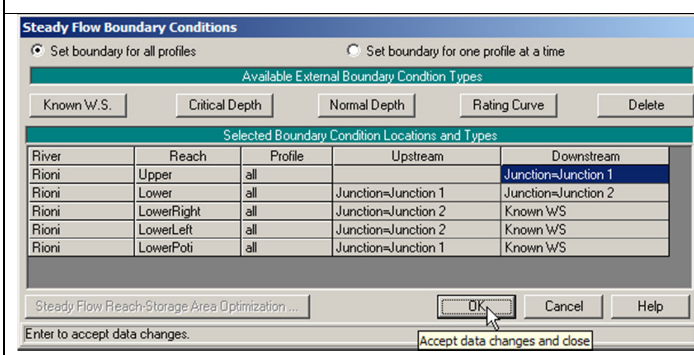


Figure 32: Final look of the interface.

This procedure of building a scenario from scratch saving it, and re-saving with other name to later modify it and build a second scenario is available everywhere in HecRas. It saves time and prevents errors up to certain extent.

Unsteady Flow analysis[2]

Tsamalashvili, 2010 study the hydrographs records available and the recurrence intervals of big floods, see Table 7.
The table shows that only average daily values have been recorded. Hourly values or less might be needed to record the maximum instantaneous peak discharge that will eventually produce outbreaks.
In this exercise we will work with 10 years hydrograph as it will be introduced in the model.
The boundary condition upstream is the flow hydrograph that should be applied to the Upstream of the Upper reach of Rioni river.

[2] CHECK POINT of the exercise. (Students should finish here the second day)

25 Select the icon "**Edit/Enter unsteady flow data**"

The "Unsteady Flow Data editor opens". As you click in any boundary condition cell the choices of possible boundary condition options highlight.

26 Select The "**Rioni-Upper**" boundary condition cell and then the highlighted "**Flow Hydrograph**" option.

The exact date of the event is not relevant as such, but it has to be consistent during the whole project. The event happened between 31 January to 11 February and we will take these dates as modeling period.

27 Enter the flow hydrograph data:

27.1 At the end of the data input the interface should look like in Figure 33. Notice that the initial discharge is repeated twice to help in the stabilization of the model before the wave comes in.

The boundary condition downstream is again controlled by the water head at the Black Sea.

Table 7: Observed flood in 1987 and estimated Recurrence intervals (after Tsamalashvili, 2010). Notice that the shape of the hydrograph is associated to the available flood of 1987.

days	1987 Observed Discharge m^3/s	10	25	50	100	200
1	236	191	226	253	279	305
2	276	223	265	296	326	357
3	780	632	750	837	923	1010
4	2120	1718	2038	2275	2510	2745
5	**3640**	**2951**	**3500**	**3907**	**4311**	**4714**
6	1720	1394	1653	1846	2037	2227
7	1550	1256	1490	1663	1835	2007
8	1060	859	1019	1137	1255	1372
9	1270	1029	1221	1363	1504	1644
10	1100	891	1057	1180	1302	1424
11	660	535	634	708	781	854
12	530	429	509	568	627	686

As the last cross section available is not yet at the sea, it is perhaps better to select a normal depth for boundary condition instead of fixing the water level.
In this example we could try a normal depth of 0.001 and then change to water head fixed if the results are not satisfactory.
The most ideal case would be to extend the cross sections towards the sea, till there is certainty that the water level in the section is not influenced by the channel constriction. As cross sections did not get the sea the selected boundary condition remains to be tested.

28 Select the three boundary conditions downstream (for the ending reaches) and set "**normal depth**" equal 0.001 in all three cases. At the end of the input the interface should look like in Figure 34.

Information: The button "**Add RS**" allows the user to input a hydrograph, structure or restriction at any station in the system. It works similarly as in the steady case. Any mechanism of input or output of water in and out from the system can be simulated using this option.

29 In the "**Unsteady flow Data**" interface, select the "**Initial Conditions**" tab. We are going to assume that the initial conditions before the storm are as expressed in Figure 35.

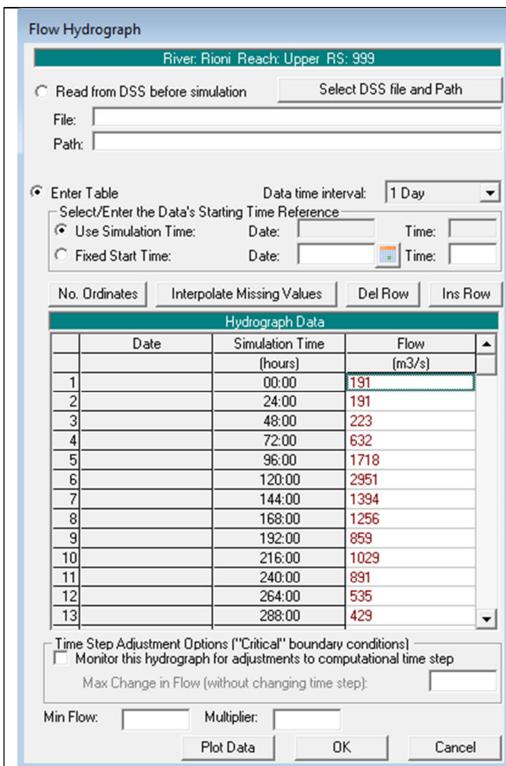


Figure 33: Flow hydrograph data input.

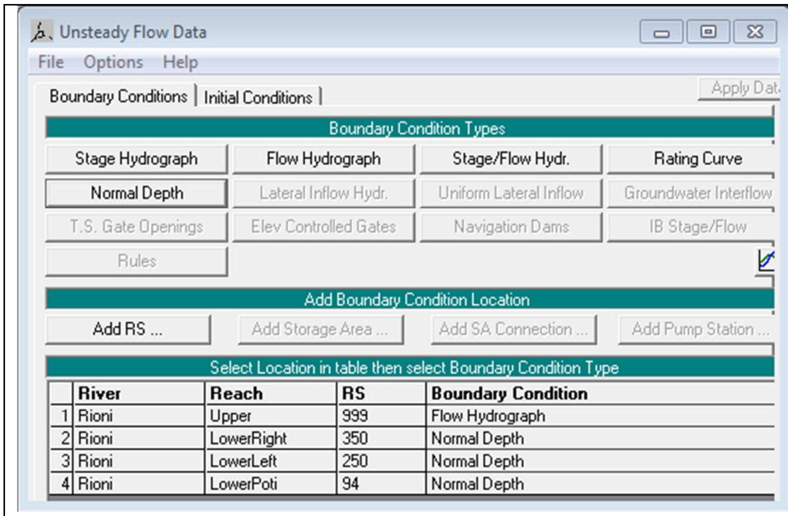


Figure 34: Boundary conditions for the unsteady case selected for the first model run.

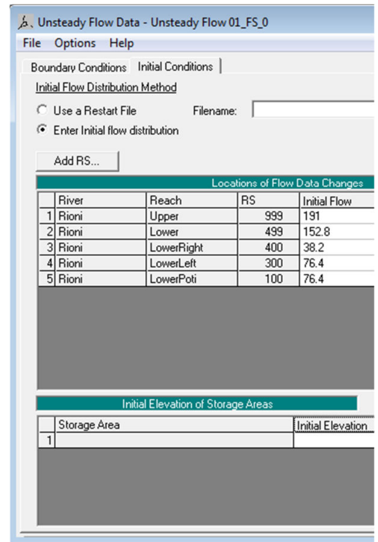


Figure 35: Initial conditions for Unsteady state. (Assumed).

Running the model and analyzing the results.

Steady Flow

30 To run the HecRas in steady flow, select the icon “**perform a steady flow simulation**” (Figure 36).

31 As the “**Steady Flow Analysis**” interface appears, select the adequate **geometry** file and **Steady flow file**. There should be 2 steady flow files, one for 0 elevations and the other for 50 cm elevation at the downstream ends.

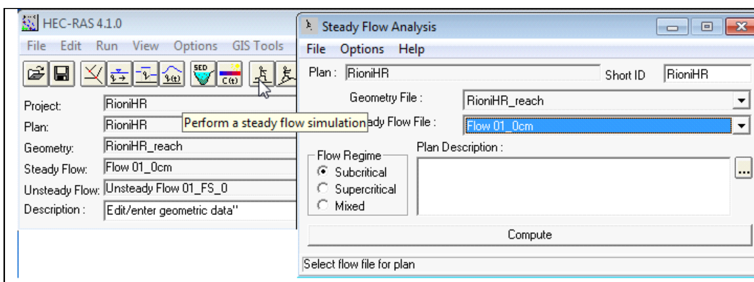


Figure 36: Interface to run the steady state

32 Select “Subcritical flow regime” and press “compute”. Calculations will be finished in seconds.

Result analysis

A deep analysis requires time and verifications. It is not expected to cover all of them in this exercise.
A reduced “check list” of controls are the following:

a) Verify that the regime type (subcritical) is the adequate.
b) Review the summary of errors, warning and notes with extreme care. In general there might errors that require attention: cross sections additions and changes in the conveyance reqiring the verification of cross sections adequacy.
c) Verify the adequacy of the selected profiles.
d) Verify the adequacy of the boundary conditions.
e) Verify the adequacy of the extent of the cross sections. Some of them might have been extended vertically to allow the model to flow. This is unacceptable.
f) Calibrate the model with available information: rating curves or water marks. This option may require refinements like the addition of structures.
g) Do the modification analysis as required.

In the following, and indication of every step is given.

Verifying the flow regime

The verification of the flow regime can be done in several ways:

- Pressing the icon "**view profile**" in the main HR interface brings a view similar to Figure 37. Reaches and profiles (up to 6 in this case), can be added pressing the corresponding buttons seen in the figure.
- From the "**options-variables**" check that critical depth is selected. If the critical depth line is below the water surface line at any progressive, then the regime is subcritical. In any other case the regime has to be modified with implications in the boundary conditions. Sometimes HR does not display the full critical line except when incompatibilities occur. So, if you don't see the critical line in the figure the regime might be correct.
- Other option is to open the "**view summary output look up tables**" icon. The table summarizes some hydraulic properties of every cross section. The last column is Froude number in the channel. Be certain that is **less than 1** at all sections to ensure subcritical flow.

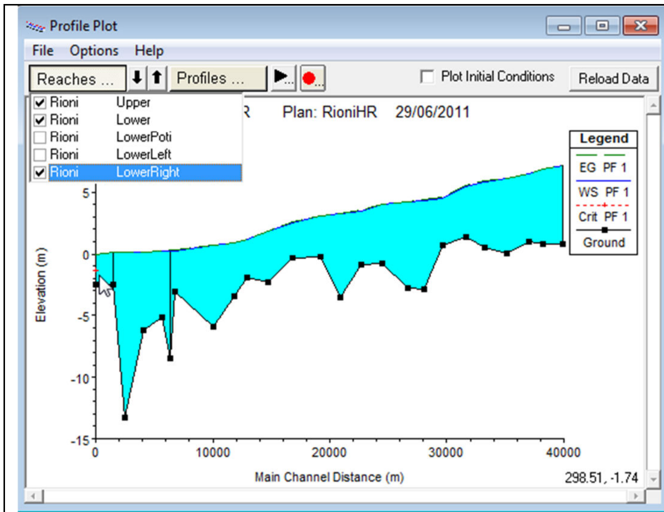


Figure 37: Longitudinal profile plot can be used to identify irregularities and the correctness of the flow regime.

Errors, warnings and notes

From the main menu click the icon "**Summary of errors, warnings and notes**". At this stage it is strictly necessary to read the corresponding section in the user manual (11-3). If any *error* happens, the program will stop. *Warnings* must be checked carefully and not *necessarily* mean that actions need to be taken. *Notes* indicate information on how the model operates.

If the energy drops or increase more than 70 or 140% between one section and the next one respectively of the conveyance sections change too much (irregular sections), then additional cross sections are normally required. This might indicate that more survey is needed. HecRas has some tools to artificially interpolate the cross sections. (see below)
Errors are written by profile, as the results are independent.

Ability of cross section interpolations

HecRas can geometrically interpolate cross sections in order to artificially create more sections than the surveyed ones.
The interpolation can be cancelled (back to original) at any time, and it is performed by a sophisticated algorithm that interpolate among two XS shapes, both geometry and roughness.
User selects the maximum distance between two sections and if it will be done for two consecutive sections, a reach, a subreach or a river.

Particularly, when interpolating between 2 cross sections, the user has the option to "force" interpolation lines between the sections. This feature allows the intervention of the user to avoid wrong interpolations done by the fully automatic procedure.
Figure 38 and Figure 39 Show the interpolation options available in HecRas. Decisions taking by the user on forcing an interpolation can be substantial in the results.

Figure 40, Figure 41 and Figure 42 shows also two options of displaying the interpolated cross sections. Notice that being a 1-D model either option is for displaying purposes only. Calculations in either case are identical.

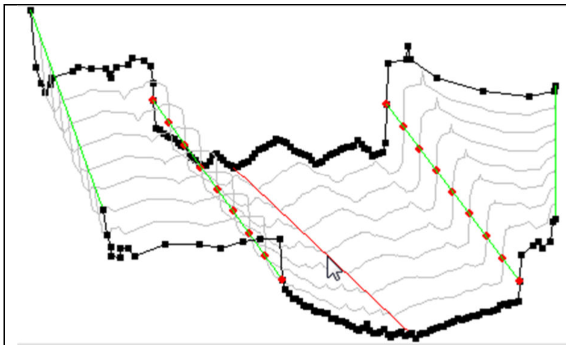


Figure 38: Interpolated cross sections between river stations 986 and 985 without forcing lines.

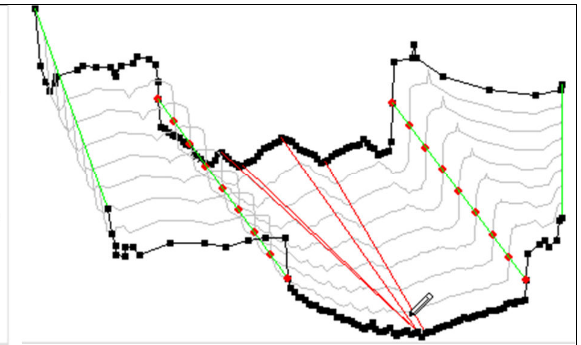


Figure 39: Interpolated cross sections between river stations 986 and 985 with 4 forcing lines.

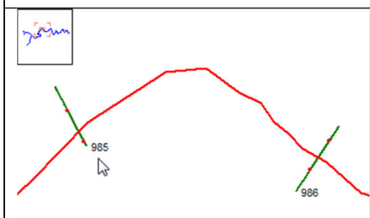


Figure 40: Planimetry of the cross sections 986 and 985.

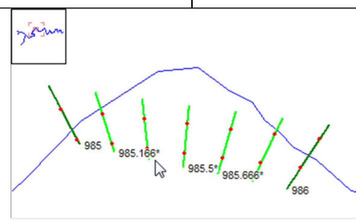


Figure 41: 5 interpolated cross sections with the option: "Linearly interpolate cut lines from bounding XS's" on.

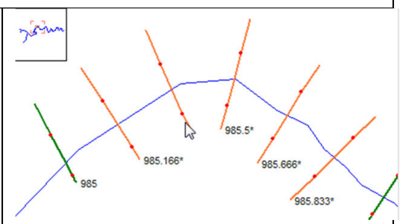


Figure 42: 5 interpolated cross sections with the option: "Generate for display as perpendicular segments to reach inverter" on.

The user should incorporate the interpolated cross sections and repeat the calculations and control the errors and warning tables.

<u>Verification of the adequacy of the profiles</u>

HecRas is robust software and sometimes produces artificial changes that allow ending the hydraulic calculations without halting. *Any kind of change done by HR will be reported as a warning*.
Figure 43 shows station 988 in the upper Rioni.
For the profile 1 (500 m^3/s) the river flows in the cross sectional area.
Again in Figure 43 for profile 4 (2000 m^3/s) the water overflows the **left bank**.
This is impossible as in the progressive 268.52 m, the elevation of the embankment is 6.12 m, meaning 0.12 m higher than the elevation of the water. This is standard behavior in HecRas. By default HR will inundate adjacent areas having elevation lower than the water level, despite that the connectivity does not allow it.
To prevent this, the user **must establish a levee** at that point in the cross section (XS 998, station 268.52).
Figure 44 shows the calculation of HECRAS when a levee is established. There is no flooding of the left overbank for profile 4.
To impose a levee, the user must select

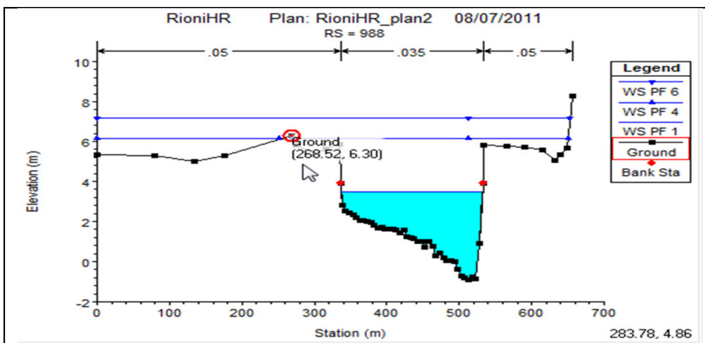


Figure 43: Three profiles represented in the cross section. For profile 1 the water level remains in the channel. For profiles 4 and 6 the software rises an "artificial wall" to the left of the left overbank to prevent overflooding and continues the calculation.

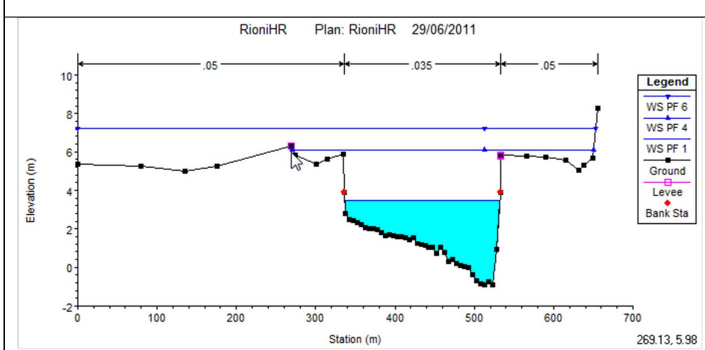


Figure 44: Same calculation as before, but now with the levee established.

the cross section where the levee is located from the **Geometric data editor**. The XS is then edited and the levee can be installed from “**option-levee**”. See Figure 45.

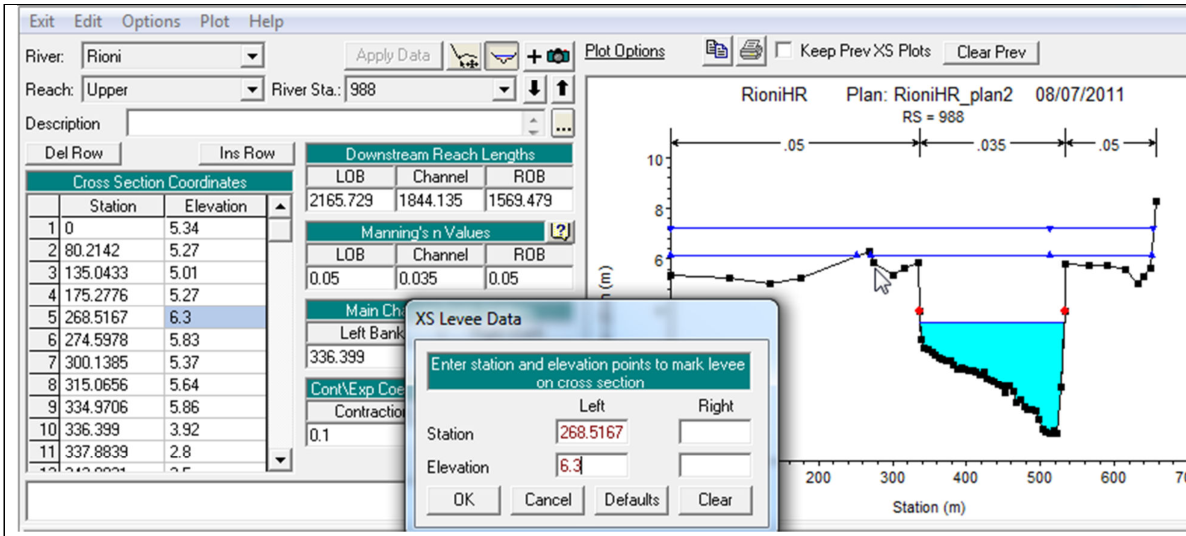


Figure 45: Levees are created from the cross section editor with the option "option-levee".

For profile 6 (3000 m^3/s) the left overbank is flooded. The left bank survey needs to be extended horizontally till a position where flood does not happen. The present survey is not extended enough and the software rises an artificial “vertical wall” at progressive “0” to continue the calculation.
This indicates that the section needs to be surveyed again till completeness and that this cross section is compromised and probably requires the construction of lateral protection structures like dikes.

<u>Control of the boundary conditions</u>

The selection of adequate boundary conditions is crucial for the modeling success. In general, modelers prefer to establish the “system under study” far away from the boundaries. In this case, if errors happen, they will be in the vicinities of the boundaries but the inner model (system) will have better results. This might not be the case in areas without slope or in case of subcritical flows with extensive backwater effects.
In the particular case of the Rioni river, the boundary downstream is the water level of the Black Sea. In this exercise a water level was supposed to be 0 and 0.5 m to evaluate the differences, but in the real case it is needed a better measurement.

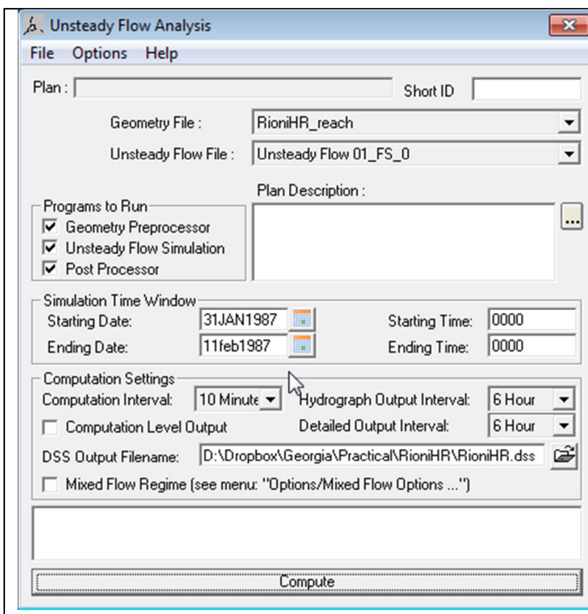


Figure 46: Interface to run the unsteady state

Modelers are reluctant to establish fix water levels as BC. This BC forces to measure cross sections to a place where no change in water elevation happens regardless of the discharge. This might be deep in the sea. A better solution could be a rating curve at the outlet, although in this case this was not available.
Notice that by fixing the water elevation we state that the profile in the last downstream sections do not change with the discharge. This is erroneous if the last cross section is constrained between banks not reaching open water yet.
The boundary condition downstream will affect the results. The advice is to establish a reasonable BC and later compare the rating curve produced by HecRas with measurements in the field.

Calibration and validation can only be done with independent measurement sources. This information is not available at the present stage of the study. Comparison of rating curves could be an easy asset to achieve validation.

Unsteady flow

33 To run the HecRas in unsteady flow, select the icon “**perform a unsteady flow simulation**”.
Figure 46 shows the input information for the unsteady flow simulation. Notice that the date and time of the simulation is stated in here and it should coincide with the information provided in the input hydrograph. Observe the format of the Date and Time fields as well.
The hydrograph information is every 24 hs. The calculation interval in this case is set to 10 minutes. HecRas interpolates the 24 hs hydrograph for the calculations. Despite that the calculations are done every 10 minutes, the software produces an output every 6 hours (selected by user) from the interface. In unsteady flow there are several options for the calculation.
User may opt for different tolerances, methods to calculate friction slopes, pre-runs to optimize the backwater effect (recommended when flowing towards the sea) and more. User needs to read the manual for advance features.
34 Input the data as stated in Figure 46 and then press “compute”.

The kinds of verifications to be made are similar to the case of steady flow. In a real case, the modeler should prevent the use of the unsteady option without validating the steady case.

35 From the main menu select the icon “view profiles”. Add the reaches as in Figure 47.

35.1 Right click inside the graph, **select variables** and choose: **Left and right banks and the water surface.**

To verify the boundary conditions in the unsteady state (normal depth), Figure 47 plots a longitudinal profile from the upper to the LowerLeft ends.

The selection of a “normal depth boundary condition, fixed to 0.001 (0.1 %) produces a discontinuity in the profile that indicates an inadequacy (see the cursor arrow in the figure).

Figure 48 shows the results of the modeling after the friction slope was reduced ten times (0.0001). The backwater effect produced by the Black Sea is then controlling the situation.

As expressed above a rating curve is perhaps the most adequate alternative as lower end BC, although the selected Boundary Conditions are adequate if the system under

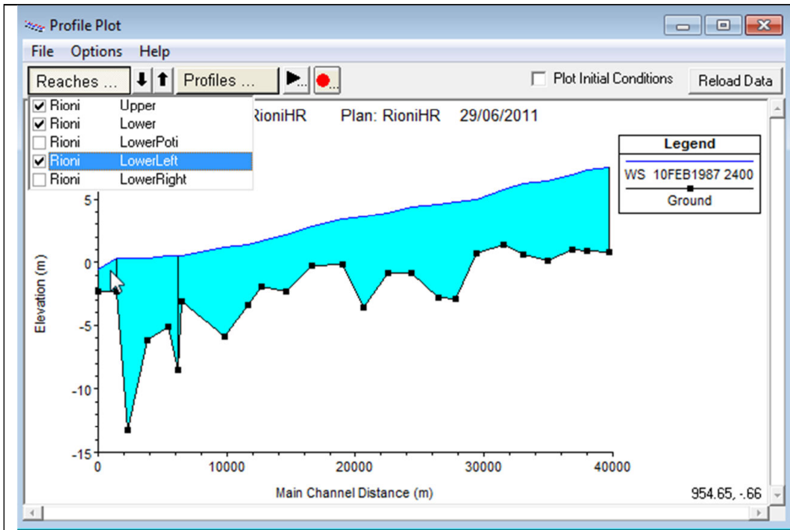


Figure 47: Longitudinal plot of the Upper, Lower and LowerLeft Rioni. The sloppy water profile at the end section may indicate a wrong selection of the boundary conditions.

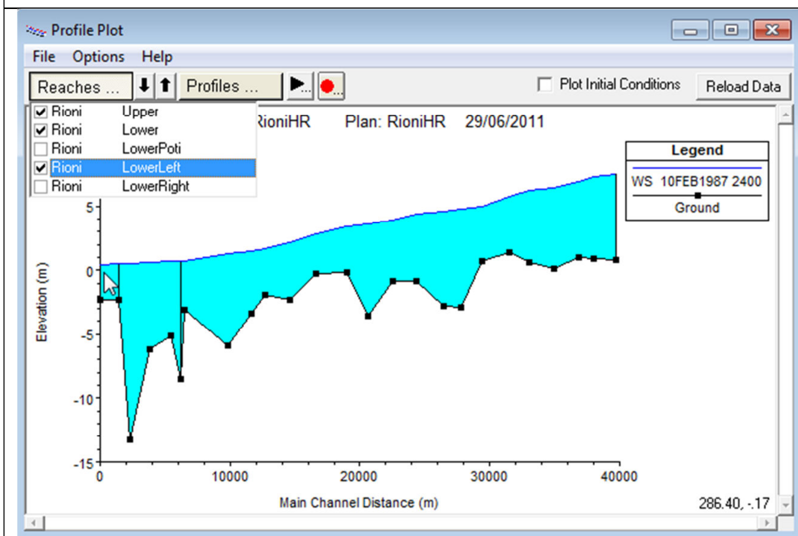


Figure 48: Modification of the boundary condition downstream from 0.001 to 0.0001 affect the profile at the lower end of the system.

analysis is restricted to the upper, lower and RioniPoti reaches.

<u>Evaluation of the critical sections</u>

In this particular project the vulnerability to flood is intimately related to the lateral protection.
Figure 49 is a “**profile plot**” showing a longitudinal profile where the left and right channel bank elevations plot together with the maximum water elevation, during the imposed flood along the Rioni. This gives an indication of the kind of effort to be done in the protective structures to contain the water laterally.

The modeler should review each cross section to identify compromised dikes in the same way as it was done in Figure 43 and Figure 44. Sectors where the model imposed a vertical extension of the cross section are critical and need further analysis.
In many occasions is not elevation the cause of problem but other hydraulic variable like velocity or

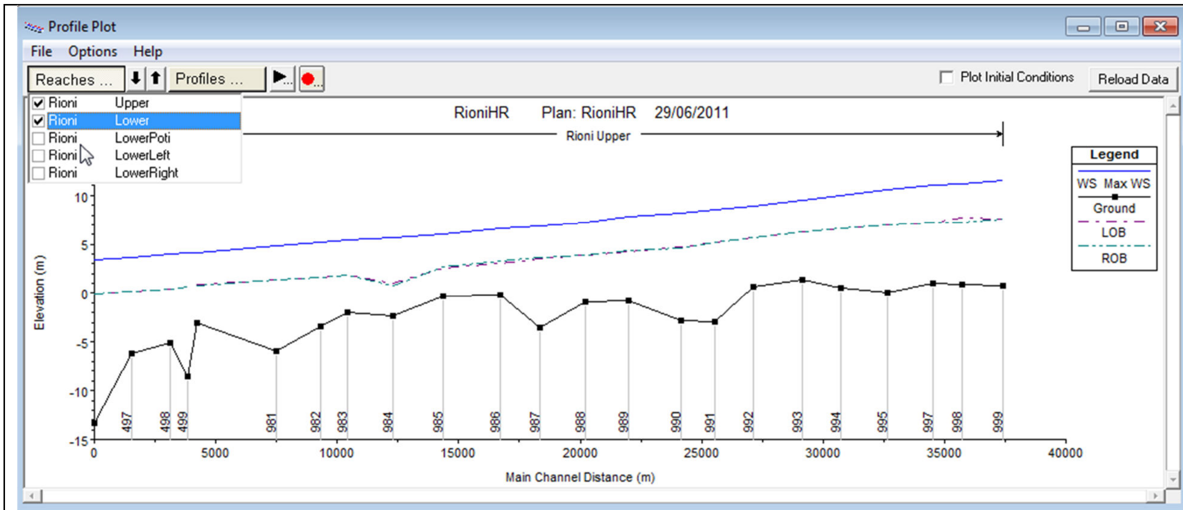


Figure 49: Longitudinal profile of the highest flood. It gives a reference of the elevation of the lateral structures.

energy causing bank erosion.
A 1-D model like HecRas has several limitations in terms of detail analysis. A 1D model always assumes that the velocity in a cross section is uniform in width and depth. As such, the software displays the average value of the speed at the cross section.

A second limitation is that as the model is 1-D it actually calculates as if the river is on a straight line, so differential forces happening in a cross section in turns and meanders are not calculated.

36 Select the icon “**View General Profile Plot**”. From the Standard plots select Velocity and from Reaches, select Upper, Lower and LowerRight.

Figure 50 shows the longitudinal plotting of hydraulic variables. In this case is the flow speed. The plotting is not smooth because the model requires more cross sections.
Notice that the information is multi-temporal: The graph shows the maximum speed in the XS that happened during the period of the run and not an instantaneous value.

Figure 50: Longitudinal information of a hydraulic variable. In this case is the maximum speed in a cross section. Notice that the calculation is done at cross sections only and since no interpolation was done the estimation have errors. Figure shows maximum speed in the channel and the LOB and ROB.

This ends up the basic HecRas analysis in this exercise. Many options remain in the software to further analysis and research. The user should investigate the list of Error, warnings and notes and do some interpolations in the model.
Users are strongly suggested to review the user manual to discover those features that are essential for their projects.

Special in HecRas

HecRas has a complete set of tools to:

- Incorporate structures in the model: Bridges, culverts, storage areas and complex in-line and lateral structures
- To analyze the result of possible remedial structures and compare to the original case.

Those are special features in engineering and require special attention to be modeled correctly. The reading of the User and Hydraulic manuals are essential.

Users are invited to review the HecRas example 2 in steady state (Single Bridge) to model bridges. The user is requested to follow the Example 2 of the Application Guide on HecRas.